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Study of Morphometric Properties and Water Balance Using Thornthwaite Method in Khanaqin Basin, East of Iraq.

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Abstract

Water balance techniques are a means of solution of important theoretical and practical hydrological problems, where morphometric analysis of a watershed provides a quantitative description of the drainage system, which is an important aspect of the characterization of watersheds. The evaluated quantities of drainage morphology in Khanaqin basin which located to the East of Iraq were Perimeters (P), length (L), width (W), circulatory ratio (Rc), elongation ratio (Re), form factor (Rf), compactness coefficient (Cc), stream order (Su), stream numbers (Nu) and lemniscate factor (K). The catchment's area was (1920) km2, characterized by is elongated low relief, gentle ground slopes and far from being circular with moderate peak flows of fifth stream order. The ratio of water surplus calculated from annual rainfall was (13.15%) and the actual evapotranspiration and soil moisture was (86.82%) according to average annual rainfall during (1990-2013) using Thornthwaite equations to calculate potential and actual evapotranspiration. The water surplus calculated as (35.973) mm distributed into (25.713) mm as natural recharge of groundwater and (10.26) mm surface runoff.

Keywords: Morphology , Water Balance , Thornthwaite method, East of Iraq.

الخلاصة

تعد تقنيات الموازنة المائية احدى الوسائل المهمة لحل المشاكل الهيدرولوجية النظرية والعملية حيث يوفر التحليل المورفومتري لمستجمعات المياه وصفاً كمياً لانظمة التصريف المائي وهو جانب مهم لبيان خصائص ومواصفات مستجمعات المياه . يتضمن هذا البحث تقييماً كمياً للخصائص المورفومترية لحوض خانقين الذي يقع في شرق العراق حيث اشتملت هذه الخصائص على مساحة الحوض ، محيط الحوض ، الطول ، العرض ، نسبة الاستدارة ، نسبة الاستطالة ، معامل شكل الحوض ، معامل الانضغاط ، والاعداد النهرية ورتبها . بينت نتائج الدراسة بان مساحة الحوض قد بلغت (١٩٢٠) كم٢ حيث تميز الحوض بتضاريس منخفضة نسبياً ، ومنحدرات أرضية بسيطة وبعيدا عن كونه دائري مع تدفق معتدل الذروة مع رتبة نهرية وصلت للدرجة الخامسة . بلغت نسبة الزيادة المائية بـ (١٣,١٥٪) فيما بلغ النقصان المائي كتبخر نتح – حقيقي ورطوبة تربة بـ (٨٦,٨٢٪) من معدل المجموع السنوي للامطار باستخدام معادلات ثورنثويت لحساب التبخر الكامن والحقيقي خلال الفترة (١٩٩٠-٢٠١٣) ، حيث كانت الزيادة المائية المتحققة في الحوض بقيمة (٣٥,٩٧٣) ملم موزعة على (٢٥,٧١٣) ملم كتغذية طبيعية للمياه الجوفية و (١٠,٢٦) ملم كجريان سطحي.

الكلمات المفتاحية :- الاشكال الارضية ، الموازنة المائية ، طريقة ثورنثويت، شرق العراق.

Introduction

Morphometric analysis provides quantitative expression of drainage basins, and is regarded as one important tool in hydrological analysis providing simple and accurate measures to document the drainage systems (Angillieri, 2008) and (Mesa, 2006). The geographic and geomorphic characteristics of a drainage basin are important for hydrological investigations involving the assessment of groundwater potential, watershed management and environmental assessment (Malik *et.al*., 2016).

Climate and hydrological conditions in any hydrological basin are multi-combined reflection of natural factors of morphology and soil nature, as well as the changing in climate factors that affect directly on hydrological cycle (Al-Sudani, 2003).

The study of the water balance structure of lakes, river basins, and ground-water basins forms a basis for the hydrological substantiation of projects for the rational use, control and redistribution of water resources in time and space. Knowledge of the water balance assists the prediction of the consequences of artificial changes in the regime of streams, lakes, and ground-water basins (Sokolov and Chapman, 1974).

Morphometric analysis of watersheds and drainage networks of Khanaqin basin plays a vital role in understanding geohydrological behavior and expressing the prevailing climate, geomorphology and structural antecedents of terrains. It involves the evaluation of streams through the measurement and analysis of various stream and drainage parameters to predict the approximate behavior of the watersheds during periods of heavy rainfall and assessment of groundwater potential, watershed management and environmental assessment when we calculate water balance components.

The study area is located in Diyala governorate in the east of Iraq and bordered by Iraqi - Iranian borders from the east and Diyala river from the west while Nadoman anticline fold and Bernand mountain chain surrounding the basin from south and north respectively. The area covers 1920 km^2 within (45º 10'- 45 º 59') E and (34 º 10 ' - 34 º 45') N, figure (1). In Iraq, many studies using remote sensing as a tool to study morphometric properties such as (Hassan, 2007) who studied morphometric properties of Mandili area in Diyala in 2007. **(**Mohammed and Taha, 2009) examined morphometric properties and geomorphological model of Kurdarah valley, east of Hamrin Lake, Iraq. (Hassan *et.al*., 2014) studied morphometric properties of Bulkana (Naft Khanah) north-east Iraq from topographic maps.

Water balance techniques, as a main subjects in hydrology, are a solution of important theoretical and practical hydrological problems. Depending on water balance approach, It is possible to make a quantitative evaluation of water resources and their change under the influence of man's activities. An understanding of the water balance is also extremely important for studies of the hydrological cycle where the relationship between rainfalls on an area with the total loss of water in different forms can be distinguished. The water balance equation can be expressed as follows (Domenico and Schwartz, 1998):

Input – Output = Change in Storage

Rainfall is the only input element in the water balance, where set of outputs as evaporation, transpiration and consumption. Evaporation reflects the loss of water from water surfaces or soil, while transpiration and consumption are a process of water evaporation from plants, these two processes are called Evapo- transpiration or potential Evapotranspiration which reflected the water losses with abundant quantity of water exist in the basin area and it can be calculated by specific equations, while actual Evapotranspiration can be determined when quantity of water is limited.

The second element of the water balance is soil moisture content, which depends on soil type, texture and depth. This element affects surface runoff and groundwater recharge, which represent the last elements of the water balance. Surface runoff or groundwater recharge is achieved only when soil is saturated (Famiglitti *et. al.*, 1998). The filtration rate decreases gradually within the time of rainwater filtration to the soil zones and surface run off can be occured at any time when rain intensity is higher than the filtration rate (before the soil moisture content is completed and reached its final level) (Domenico & Schwartz, 1998). Soil moisture content is measured either by laboratory calculation of soil saturation ratio or by field using Lysemeters techniques.

The potential evapotranspiration can be calculated by experimental equations as Thornthwaite equation (Thornthwait, 1948). This variable is often with high values and greater than the rainfall quantity (if exist) at the time when temperatures is high, which generates a water deficit in the basin and at the same time, this variable values fall to the lowest level in a period of low temperatures accompanied by increasing rate of rainfall which generates a water surplus.

Most hydrological science researchers supposed that potential evaportranspiration is equal to actual evapotranspiration when rainfall is greater than potential evapotranspiration. Thus, the water surplus can be divided into run off and natural groundwater recharge after soil moisture saturation is complete (Al-Sudani, 2003).

P > PE ----- PE = Eta --------- (1)

WS = P – Eta --------- (2)

And WS = Ro + Re + SM --------- (3)

P: Rainfall, PE: potential evapotranspiration, ETa: actual evapotranspiration, WS: water surplus, Ro: surface runoff, Re: groundwater recharge, SM: soil moisture.

The actual evapotranspiration will be equal to the rainfall when rainfall is less than potential evapotranspiration, even so, this assumption does not represent the actual reality where actual evapotranspiration in the second period which characterized by increasing values of potential evapotranspiration and decreasing of rainfall will make potential evapotranspiration is equal to rainfall and soil moisture content exist in soil zone which will be gradually exploited by the plant to achieve the water demands in the basin as a result of decreasing rainfall quantity as well as increased values of evaporation and transpiration or losing soil moisture automatically related to increasing of temperatures in this period. The actual evapotranspiration will be the same as potential evapotranspiration as in the first period but for a short time (only few months). Whenever the sum of total soil moisture content and rainfall is higher than potential evapotranspiration, then rainfall will be greater than potential evapotranspiration, and when soil moisture or rainfall or both begins gradual and naturally decrease in this period below potential evapotranspiration values, then the actual evapotranspiration will be equal to water amount exist in the basin as a soil moisture storage or rainfall. Finally, whenever rainfall and soil moisture content are absent, the actual evapotranspiration will be zero because there is no water can evaporate or be transpires by the plant (Al-Sudani, 2003).

P < PE -------- WS = 0☐

If P + SM > PE

Then PE = Eta

If P + SM < PE

Then P + SM = Eta

WD = PE - (P+ SM) -------- (4)

W.D.: Water Deficit.

It seems from above equations that soil moisture in the first period (P> PE) will be an acquired component in the water balance, where a quantity of rainwater is exploited before generation of surface runoff and groundwater recharge. In the second period (P <PE) it seems that soil moisture is a missing component in the water balance for its contribution with the precipitation in actual Evapotranspiration.

Geological Setting:

Khanaqin basin is built up by geological formations ranging in age from Upper Jurassic up to Recent. The basin is built up by folded sedimentary sequence. The upper unit of Bai Hassan formation (Upper Bakhtiari formation - Pliocene) which covers the older rocks by clear angular unconformity is considered as Bamu formation (Pleistocene), (Barwary and Said, 1992) figure (2). Structurally, the majority of the basin belongs to the Foot-hill Zone of Iraq. Geomorphologic, the area has been divided into three morph-genesis units. (Barwary and Said, 1992)

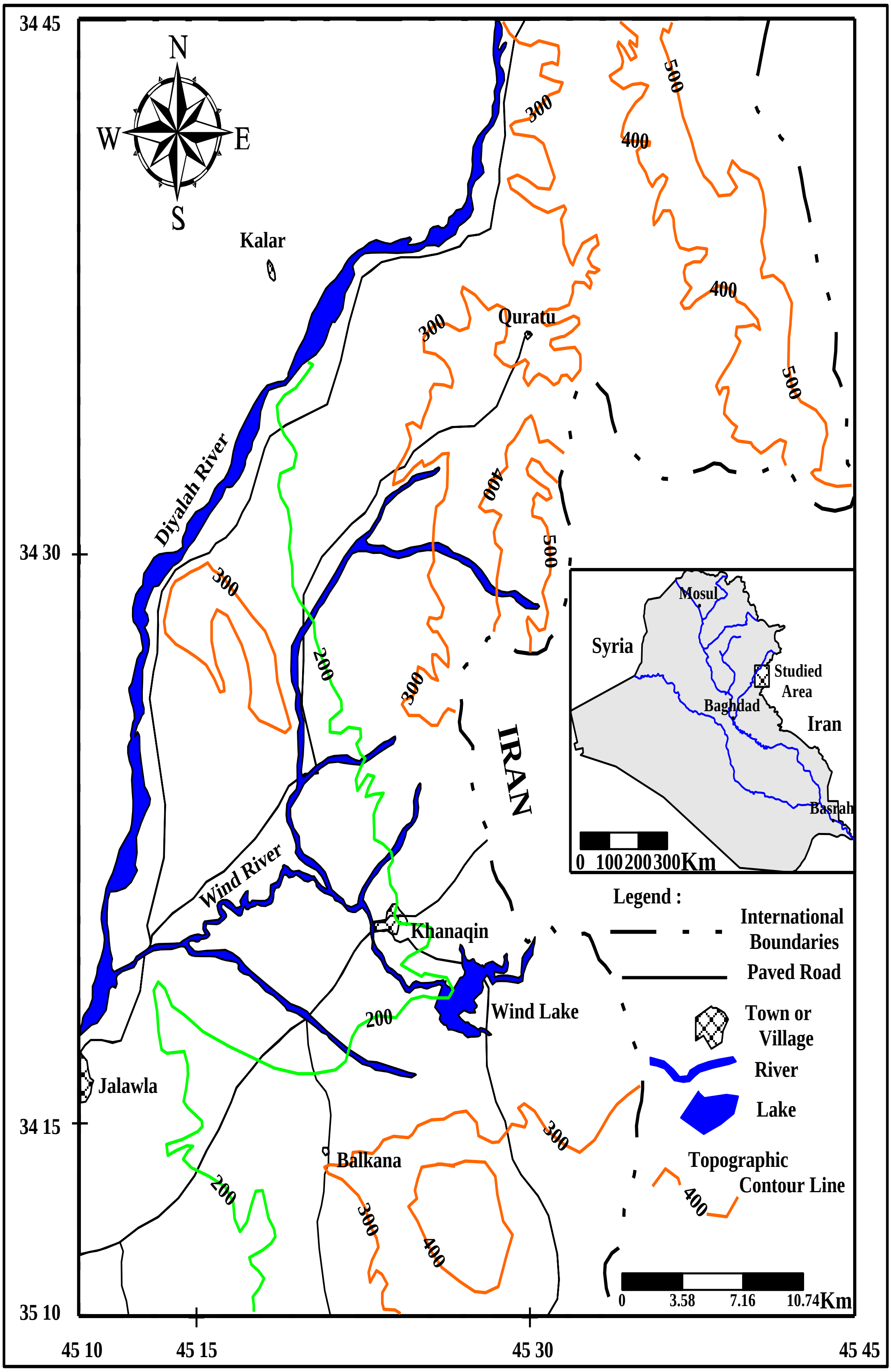

Fig (1): Location and Topography map of Khanaqin Basin (General state of Surveying, 2014)

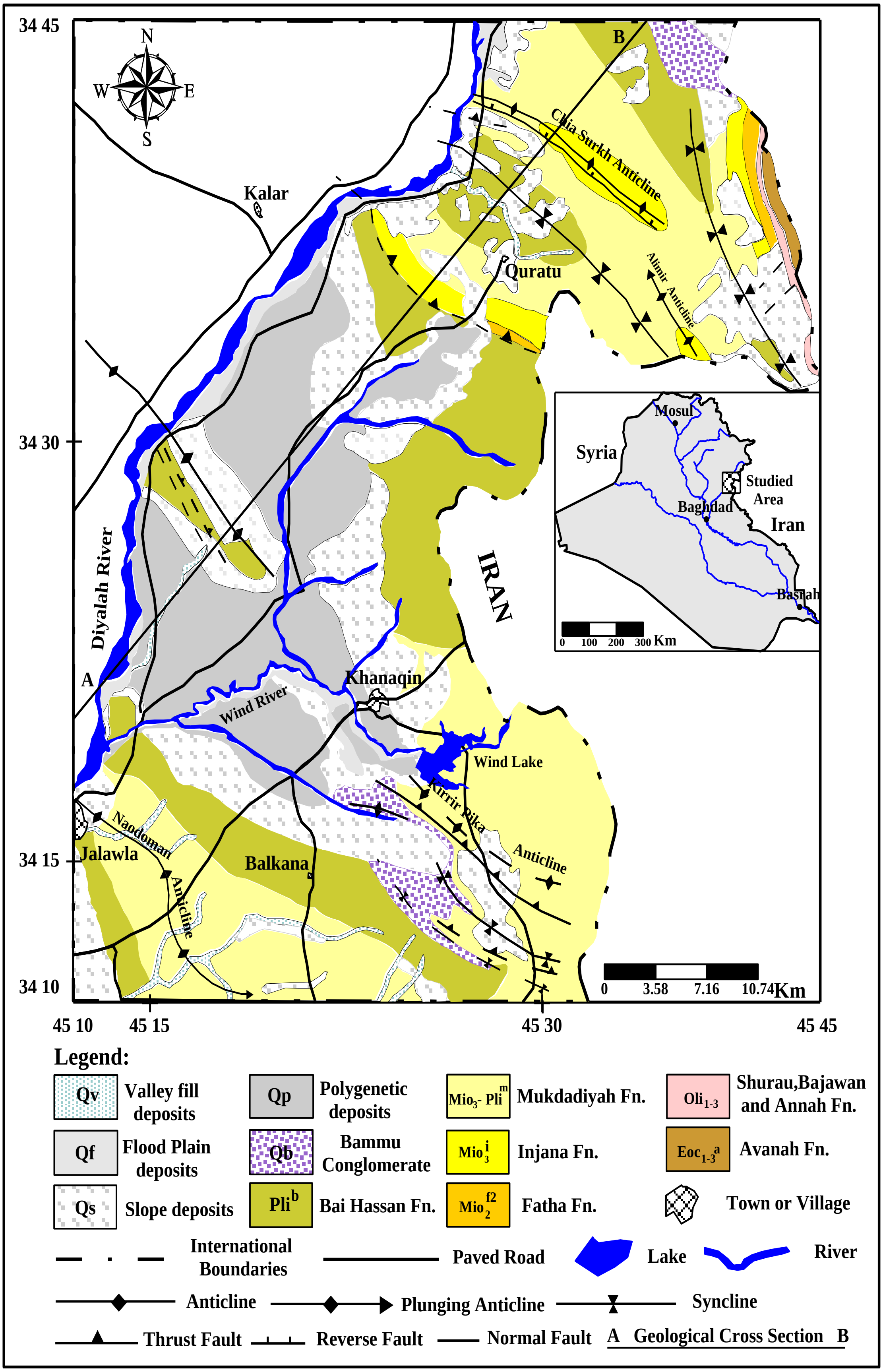

Fig (2): Geological Map of Khanaqin Basin (Barwary and Said, 1992).

Results and Dissection :

1- Morphometric Properties of the Basin:

1.1- Basin Area (A): It is the area of land where all surface water converges to a single point at a lower elevation. The area of the watershed is another important parameter like the length of the stream drainage. The surface water may include rain, melting, snow or ice which join rivers, lakes reservoirs, estuaries, wetlands , seas or oceans. The lower elevation single point of the basin in another hand usually become the exit of the basin (Allison, 2002). The drainage or catchment area of Khanaqin basin divided into two parts where the first one located inside Iranian territory, while the second part located within Iraqi territory. the calculation of catchment area depends on ArcView 3.2 software for 1920 km^2 from topographic map. Table (1) shows some morphological characteristics of studied area.

1.2- Basin Perimeter (P): The outer boundary that enclosed the watershed area defined as basin perimeter. It may be used as watershed size and shape indicator where it can be measured along the divides between watershed (Anderson and Anderson, 2010). The perimeter of Khanaqin basin was 180 km.

1.3- Basin Length (L): (Schumm ,1956) indicate that basin length is the longest dimension of the basin parallel to the principal drainage line. Calculation of basin length was (70) km.

1.4-Circularity (Rc): Circularity ratio is defined as the ratio of watershed area to the area of a circle having the same perimeter as the watershed and it is pretentious by the lithological character of the watershed (Pike *et.al.*, 2009). The circularity of Khanaqin basin was found to be (0.74) from topographic map, this shows that the basin is elongated more than to circle shape.

1.5- Elongated Ratio (Re): (Schumm, 1956) defined it as the ratio of diameter of a circle of the same area as the basin to the maximum basin length. (Strahler,1964) states that this ratio runs between (0.6) and (1.0) over a wide variety of climatic and geologic types. The varying slopes of watershed can be classified with the help of the index of elongation ratio, i.e. circular (0.9-0.10), oval (0.8-0.9), less elongated (0.7-0.8), elongated (0.5-0.7), and more elongated (< 0.5). Values of (1.0) are typical of very low relief regions, whereas values of 0.6 to 0.8 are indicates high relief and steep ground slope regions (Coblentz *et.al*., 2014). The results show that elongated ratio of the basin was (0.7) which means that the basin is elongated with low relief, gentle ground slopes and far from being circular.

1.6- Form Factor (R.f): It is a numerical index used to represent different basin shapes with value between (0.1) to (0.8) and may defined as the ratio of basin area to square of the basin length (Huggett, 2007). The value of form factor would always be less than (0.754) (for a perfectly circular watershed) where smaller form factor values indicate more elongated of watershed and watershed with high form factors have high peak flows of shorter duration (Horton,1932). The form factor of Khanaqin basin was (0.39) which means the basin have moderate peak flows.

1.7- Compactness Coefficient (Cc): It is used to express the relationship of a hydrologic basin to that of a circular basin having the same area as the hydrologic basin (Huggett, 2007). The compactness coefficient is dependent only on the slope of the watershed. The results show that the basin has (1.15) which reflects the elongated shape of the basin.

1.8- Lemniscate Factor (K) : Lemniscate factor indicate to the similarity between the shape of the basin and pear shape, because most of the basins tend to have pear-shaped rather than the completely circular shape (Chorley *et.al*., 1957) . The high values of this factor indicate the increasing in the elongation of the basin, while the low values indicate to the flattening of the basin which cause increasing in length and numbers of low order streams. Lemniscate Factor is denoted by (K) and it is measured by dividing the square of basin length by 4 times the area of the basin as in equation. the calculation was (0.63) which means that basin is closest to the elongation.

1.9- Stream Order (Su): Quantitative analysis of watershed start with stream ordering. Strahler's system (Strahler,1964) which is a slightly modified of Horton system (Horton, 1945), has been followed because of its simplicity . The calculation of stream order in Khanaqin was fifth order.

1.10- Stream Number (Nu): It is the total number of stream segments present in each order (Strahler,1964). The calculations of stream number in each order were 6713, 2481, 867, 446 and 292 respectively.

Table 1: Morphometric Properties of Khanaqin basin

Morphological characteristic	Topographic map
Area of Khanaqin basin (A)	1920 km^2
Perimeter of basin (P)	180 km
Length of basin (L)	70 km
Width of basin	27.42 km
Circularity (Rc)	0.74
Elongated ratio(Re)	0.7
Form Factor (Rf)	0.39
Compactness Coefficient (Cc)	1.15
Lemniscate Factor (K)	0.63
Stream Order (Su)	5

2- Climate :

Depending on Khanaqin Meteorological station located in the mid of the basin and its monthly and annual parameters during (1990-2013) mentioned in table (2) and figure (3), the climate classified according to (Doornbos and Pruitte, 1977) as continental humid to semi humid climate with average annual rainfall (273.38) mm, light wind speed not exceed (1.76) m/sec., with general decreasing of sunshine hours below (11) hours /day.

3- Water Balance Calculation:

Potential Evapotranspiration was calculated by applying (Wilson,1984) Formula:

$$PE = 16\left[\frac{10tn}{J}\right]^{a} \quad \text{-------- (5)}$$

$$\boldsymbol{J = \sum_{1}^{12} j} \quad \text{-------- (6)}$$

$$j = \left[\frac{tn}{5}\right]^{1.514} \quad \text{-------- (7)}$$

$$\boldsymbol{a = 0.016J + 0.5} \quad \text{--------- (8)}$$

PE: potential evapotranspiration, J: Heat Index, j: Coefficient monthly temperature (° C), a: Constant, tn: Average monthly temperature (° C).

Depend on the climatic data shown in table (2), and using Thornthwaite equation, the actual and potential evapotranspiration which calculated and the results shown in table (3). The water surplus in the basin was (35.973) mm divided into natural recharge of groundwater and surface runoff in seasonal valleys and rivers. Soil moisture content was calculated depending on (Jassim, 1981) specification where soil tissue was sandy clay, free of calcium carbonate with depth ranged from (100-95cm) and 25-25% of gypsum. The soil moisture was estimated at (105) mm, where this variable assume as a water deficit.

Table (2): Monthly average of meteorological parameters of Khanaqin station (1990-2013) (Iraqi General Organization for Meteorological Information, 2014).

Month	P (mm)	T (ºC)	Epan (mm)	R.H. (%)	U_2 (m/sec)	Sun S. (H)
Oct.	12.2	25.41	58.17	39.9	1.26	7.67
Nov.	48.61	17.06	103.2	60.5	1.11	6.65
Dec.	41.06	12.01	180.1	71.8	0.98	5.29
Jan.	58	9.96	239.5	76.56	1.26	5.45
Feb.	37.9	12.09	335.8	96.4	1.47	6.02
Mar.	41.37	15.99	468.2	56.5	1.64	6.88
Apr.	28.4	22.3	543.7	48.2	1.61	7.35
May	5.7	29.09	525.7	37.3	1.76	8.74
June	0.04	36.75	399.6	27.1	1.49	10.58
July	0.04	36.55	267.5	25.8	1.49	10.5
Aug.	0.00	35.72	127.9	26.8	1.34	9.41
Sep.	0.06	31.17	72.17	30.7	1.3	9.42
Sum	273.38	-	3321.54	-	-	-

R.H: relative humidity (%) , U_2 : wind speed on 2 meters height, Sun S. : sun shine duration (hours).

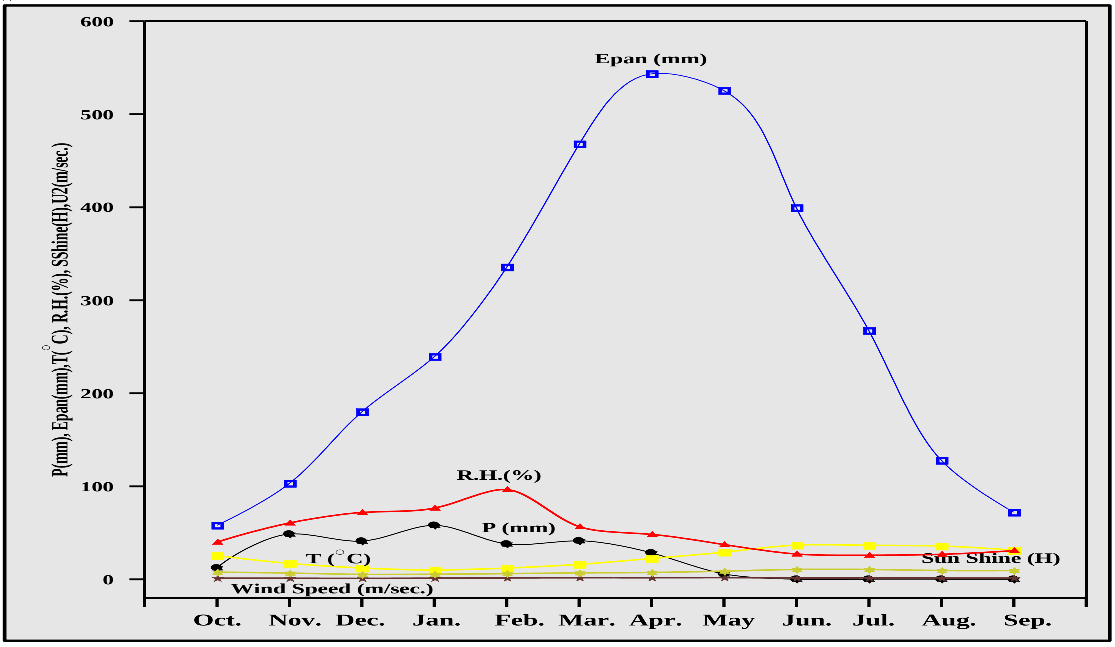

Fig (3) : Monthly Meteorological Parameters distribution of Khanaqin Station during (1990-2013)

Table (3): Water balance calculation depending on average monthly parameters of Khanaqin station (1990-2013)

Month	P (mm)	T ° C	PE (mm)	ETa (mm)	S.M. (mm)	WS (mm)	WD (mm)
Oct.	12.2	25.41	86.16	12.2	0.0	0.0	73.96
Nov.	48.61	17.06	29.92	29.92	18.69	0.0	0.0
Dec.	41.06	12.01	11.728	11.728	48.012	29.332	0.0
Jan.	58	9.96	7.152	7.152	98.86	50.848	0.0
Feb.	37.9	12.09	11.989	11.989	105	19.771	0.0
Mar.	41.37	15.99	25.168	25.168	105	16.202	0.0
Apr.	28.4	22.3	60.8	60.8	64.6	0.0	0.0
May	5.7	29.09	123.36	70.3	0.0	0.0	53.06
June	0.04	36.75	229.76	0.04	0.0	0.0	229.72
July	0.04	36.55	226.4	0.04	0.0	0.0	226.36
Aug.	0.00	35.72	212.8	0.0	0.0	0.0	212.8
Sep.	0.06	31.17	148.32	0.06	0.0	0.0	148.26
Sum	273.38	-	1173.552	132.39	105	35.973	1041.16

The annual runoff in the Khanaqin basin was calculated using (Dandekar & Sharma, 1989) mathematical formula:□

$$Ro = \frac{[P - 17.8] \quad P}{254} \qquad \text{--------} \ (9)$$

Ro: Surface runoff (cm), P: annual rainfall (cm).

The surface runoff calculated in the basin was (10.26) mm while groundwater recharge was (25.713) mm. Generally the ratio of water surplus calculated from annual rainfall was (13.15%) , while water deficit ratio was (48.42%) as actual evapotranspiration and (38.4%) as soil moisture, figure (4).

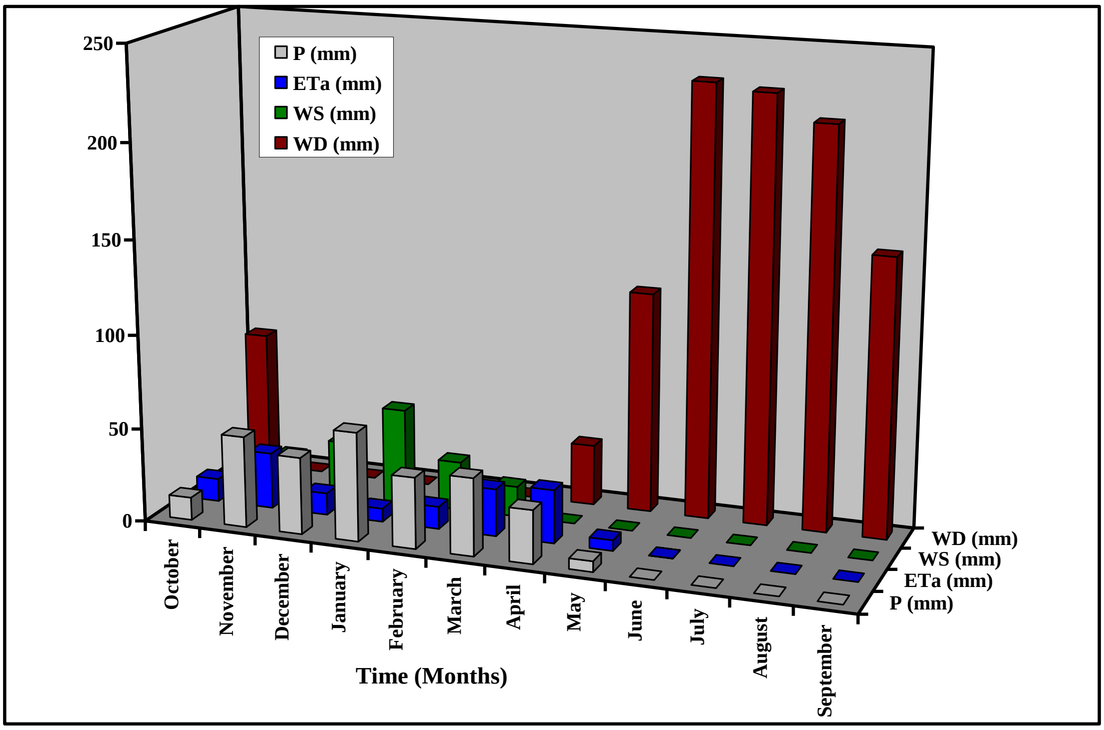

Figure (4): Water Surplus and Deficit distribution.

Conclusions:

1- The Morphometric properties of Khanaqin basin area characterized by perimeter of 160 km. The catchment area was (1920) km^2, and circularity of the basin was found to be (0.74) shows that the basin is elongated more than to circle shape. The elongation ratio (Re) of the basin was (0.7) which means that the basin has low relief, gentle ground slopes and far from being circular. The form factor for catchment area of Khanaqin was (0.39) which indicates elongated basin with moderate peak flow. Compactness coefficient of the basin was (1.15) which reflects the elongated shape of the basin. The calculation of stream order in Khanaqin was fifth order, were 6713, 2481, 867, 446, and 292 were the stream number of each stream order respectively. This indicated that a first order stream is localized in low zone.

2- The climate classified as continental humid to semi humid climate with average annual rainfall (273.38) mm, light wind speed not exceed (1.76) m/sec., with general decreasing of sunshine hours below (11) hours /day.

3- The water surplus in the basin was (35.973) mm divided into natural recharge of groundwater and surface runoff. The soil moisture was estimated as (105) mm, where this variable assume as a water deficit. The surface runoff calculated in the basin was (10.26) mm while groundwater recharge was (25.713) mm.

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